The opinion in support of the decision being entered today was *not* written for publication and is *not* binding precedent of the Board.

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE BOARD OF PATENT APPEALS
AND INTERFERENCES

Ex parte YOSHINOBU AOYAGI,
SOUHACHI IWAI, and
HIDEKI HIRAYAMA

Appeal 2006-2646
Application 09/941,612
Technology Center 1700

Decided: April 27, 2007

Before CHUNG K. PAK, THOMAS A.WALTZ, and
CATHERINE Q. TIMM, *Administrative Patent Judges*.

PAK, *Administrative Patent Judge*.

DECISION ON APPEAL

This is a decision on an appeal from the Examiner's final rejection of claims 4 through 21 and 26 through 36. Claims 22 through 25, the other claims pending in the above-identified application, stand withdrawn from consideration by the Examiner as being directed to a non-elected invention. We have jurisdiction pursuant to 35 U.S.C. §§ 6 and 134.

I. APPEALED SUBJECT MATTER

The subject matter on appeal is directed to "[a]n impurity doping method for semiconductor wherein a crystal layer made of crystal raw materials is doped with impurities...." (*see*, e.g., claims 21, 26, 27 and 28). According to the Appellants (Br. 3 and Specification 3-6), the novel aspect of this appealed subject matter lies in the timing of the introduction of impurities. Details of the appealed subject matter are recited in representative claims 21, 26, 27, and 28, which are reproduced below:

> 21. An impurity doping method for semiconductor wherein a crystal layer made of crystal raw materials is doped with impurities, comprising:
>
> a cycle composed of:
>
> a first step wherein a supply of trimethylgallium (TMGa) and biscyclopentadienyl magnesium ($(Cp)_2Mg$) is started at a first timing, and the supply of TMGa and $(Cp)_2Mg$ is finished at a second timing at which the supply TMGa and $(Cp)_2Mg$ for a predetermined period of time was completed;
>
> a second step wherein a supply of tetraethylsilane (TESi) is started either immediately after, or after the second timing at which the supply of TMGa and $(Cp)_2Mg$ was finished, and the supply of TESi is finished at a third timing at which the supply of TESi for a predetermined period of time was completed;
>
> a third step wherein a supply of ammonia (NH_3) is started either immediately after, or after the third timing at which the supply of TESi is finished, and the supply of NH_3 is finished at a fourth timing at which the supply of NH_3 for a predetermined period of time was completed; and

a fourth step wherein a purge time is started after the supply of NH_3 is finished at the fourth timing at which the supply of NH_3 was completed, and said purge time is finished at a fifth timing;

impurity pairs being formed as a donor-acceptor complex in said first and second steps using co-doping causing a decrease in activation energy and an increase in carrier concentration in said crystal layer

said first through fourth steps being repeated a desired number of times.

26. An impurity doping method for semiconductor wherein a crystal layer made of crystal raw materials is doped with impurities, comprising:

supplying as one cycle each of said crystal raw materials, one at a time and separated by a purge time; and

supplying each of plural types of impurity raw materials for a given time, where the given time for supplying each of the impurity raw materials are close to each other;

forming impurity pairs as a donor-acceptor complex in said crystal layer from said plural types of impurity raw materials using co-doping to cause a decrease in activation energy and to increase carrier concentration in said layer.

27. An impurity doping method for semiconductor wherein a crystal layer made of plural types of crystal raw materials is doped with impurities, comprising:

supplying as one cycle each of said plural types of crystal raw materials, one at a time and separated by a purge time; and

supplying each of plural types of impurity raw materials for a given time, wherein said given times either are at the same time of or after the start of supplying one of said crystal raw materials as well as before starting the supply of other of said crystal raw materials;

forming impurity pairs as a donor-acceptor complex in said crystal layer from said plural types of impurity raw materials using co-doping to cause a decrease in activation energy and to increase carrier concentration in said layer.

28. An impurity doping method for semiconductor wherein a crystal layer made of plural types of crystal raw materials is doped with impurities comprising:

alternately supplying as a single cycle first and second crystal raw materials with purge times between the supply of the first crystal raw material and the supply of the second crystal raw material;

supplying a first impurity raw material and a second impurity raw material at given times which are close to one another and either at the same time of or after the start of supplying of said first crystal raw material as well as before starting the supply of said second crystal raw material;

forming impurity pairs as a donor-acceptor complex in said crystal layer from said plural types of impurity raw materials using co-doping to cause a decrease in activation energy and to increase carrier concentration in said layer.

II. PRIOR ART

As evidence of unpatentability of the claimed subject matter, the Examiner has relied upon the following references[1]:

Daly	US 5,231,298	Jul. 27, 1993
Nishizawa	US 5,693,139	Dec. 2, 1997
Edmond	US 5,739,554	Apr. 14, 1998
Manabe	US 6,472,690 B1	Oct. 29, 2002

III. REJECTIONS

The Examiner has entered the following rejections:

1) Claims 4 through 21, 26 through 28, and 33 through 36 under 35 U.S.C. § 103(a) as unpatentable over the combined disclosures of Nishizawa and Edmond;

2) Claims 21 and 33 through 36 under 35 U.S.C. § 103(a) as unpatentable over the combined disclosures of Nishizawa, Edmond, and Manabe;

3) Claims 29 through 32 under 35 U.S.C. § 103(a) as unpatentable over the combined disclosures of Nishizawa, Edmond, and Daly; and

4) Claim 32 under 35 U.S.C. § 103(a) as unpatentable over the combined disclosures of Nishizawa, Edmond, Manabe, and Daly.

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[1] The Examiner has referred to U.S. Patent 4,028,720 issued to Pankove on June 7, 1977 and U.S. Patent 5,799,027 issued to Anayama et al. on August 25, 1998 at page 6 of the Answer. However, they have not been positively relied on in the statements of the rejections set forth in the Answer. Accordingly, we will not consider them in determining the propriety of the Examiner's rejections. *In re Hoch*, 428 F.2d 1341, 1342 n.3, 166 USPQ 406, 407 n.3 (CCPA 1970) ("[W]here a reference is relied on to support a rejection, whether or not in a 'minor capacity,' there would appear to be no excuse for not positively including the reference in the statement of [the] rejection.").

IV. ISSUES:

REJECTION 1:

1. Would one of ordinary skill in the art have been led to employ the donor and acceptor impurities taught by Edmond in the manner taught by Nishizawa in Nishizawa's process for growing doped semiconductor monolayers (crystal layers)?

2. Would one of ordinary skill in the art have been led to employ TESi, in lieu of silane gas, in the process suggested by Nishizawa and Edmond?

REJECTION 2:

3) Would one of ordinary skill in the art have been led to employ the donor and acceptor impurities taught by Edmond and Manabe in the manner taught by Nishizawa in Nishizawa's process for growing doped semiconductor monolayers (crystal layers)?

4) Would Nishizawa, Edmond and Manabe have suggested introducing the impurities in a pulsed manner?

REJECTIONS 3 AND 4:

5) Would Nishizawa, Edmond, Daly and optionally Manabe have suggested employing appropriate or optimum proportions of the donor and acceptor impurities to avoid "disorder" in semiconductor monolayers (crystal layers)?

V. PRINCIPLES OF LAW

Under 35 U.S.C. § 103, the obviousness of an invention cannot be established by combining the teachings of the prior art references absent some teaching, suggestion or incentive supporting the combination. *ACS Hosp. Systems, Inc. v. Montefiore Hosp.*, 732 F.2d 1572, 1577, 221 USPQ 929, 933 (Fed. Cir. 1984). This does not mean that the cited prior art references must specifically suggest making the combination. *B.F. Goodrich Co. v. Aircraft Braking Systems Corp.*, 72 F.3d 1577, 1582, 37 USPQ2d 1314, 1318 (Fed. Cir. 1996); *In re Nilssen*, 851 F.2d 1401, 1403, 7 USPQ2d 1500, 1502 (Fed. Cir. 1988). Rather, the test for obviousness is what the combined teachings of the prior art references would have suggested to those of ordinary skill in the art. *In re Young*, 927 F.2d 588, 591, 18 USPQ2d 1089, 1091 (Fed. Cir. 1991); *In re Keller*, 642 F.2d 413, 425, 208 USPQ 871, 881 (CCPA 1981). In evaluating the prior art references for a suggestion, it is proper to take into account not only the specific teachings of the references, but also the inferences which one skilled in the art would reasonably be expected to draw therefrom. *In re Preda*, 401 F.2d 825, 826, 159 USPQ 342, 344 (CCPA 1968).

"[D]iscovery of an optimum value of a result effective variable in a known process is ordinarily within the skill of the art." *In re Boesch*, 617 F.2d 272, 276, 205 USPQ 215, 219 (CCPA 1980).

VI. FACTUAL FINDINGS AND ANALYSES

A. Claims 4 through 21, 26 through 28, and 33 through 36 under 35 U.S.C. § 103(a) stand rejected as unpatentable over the combined disclosures of Nishizawa and Edmond.

ISSUE 1 (Claims 4 through 20, 26 through 28, and 33 through 35):

We find that Nishizawa broadly teaches (col. 3, ll. 37-67) that:

> One aspect of the present invention is directed to a method of doping a compound semiconductor single crystal layer being grown in monolayers on a heated substrate in a growth chamber by alternate introduction of source gases, the growth chamber being evacuated continuously at a continuous rate of evacuation throughout the whole method. The method comprises the steps of:
>
> (a) introducing a first source gas containing one constituent element of the compound into the growth chamber of at least a sufficient quantity for growing one monolayer, the supply of the first source gas being thereafter stopped and the growth chamber still being kept under the continuous rate of evacuation to evacuate residual of the first source gas;
>
> b) introducing a second source gas containing another constituent element of the compound into the growth chamber of at least a sufficient quantity for growing one monolayer, the supply of the second source gas being thereafter stopped and the growth chamber still being kept under the continuous rate of evacuation to evacuate residual of the second source gas;
>
> c) doping an impurity gas into the growth chamber, the impurity gas being of a particular type and having impurities which enter into sites in the monolayer being grown;
>
> d) initially carrying out steps (a), (b) and (c) to grow a monolayer on the substrate and then growing monolayers one over the other by cyclically repeating steps (a), (b) and (c) to grow new monolayer on the monolayer just previously grown
> . . .

This broad teaching is consistent with the Examiner's specific findings at pages 4 and 5 of the Answer shown below:

> Nishizawa et al discloses a method of growing doped semiconductor monolayers, note entire reference, comprising raw material gases of Gallium (Ga) and Arsenic (As), where Ga is supplied for 0.5 to 10 seconds, the chamber is evacuated, this reads on applicant's purged for a predetermined time, and As is supplied for 2 to 200 seconds and the cycle is repeated (col 7, ln 1-67; col 8, In 1-30 and Fig 7B and Fig 11). Nishizawa et al also discloses a p-type layer is formed by introducing an impurity gases [sic, gas] and Ga simultaneously but alternately with an As source, where the impurity gas is an Mg, Zn or Cd containing gas or [s]ilane. Nishizawa et al also discloses a[n] n-type layer doped with Se or S and the impurity gas is introduced cyclically with the Ga gas and As gas or the impurity gas and Ga gas are introduced simultaneously but alternately with the As gas (col 8, In 31-60). . . . Nishizawa et al also discloses nozzles 44, 45 and 46 for introducing gaseous compounds used for impurity doping for introducing group II, IV and VI gases (col 10, In 50-67). Nishizawa et al also discloses different modes of doping, where the dopant is added at . . . the introduction of a Ga gas, the exhaustion of a Ga gas . . . (col 11-13 and Fig 11) . . . Nishizawa et al also discloses introduction of a Ga source gas and a group II dopant simultaneously to form a p-type layer (col 8, In 30-45) and the introduction of a group IV dopant after the introduction of a Ga source gas (col 15, In 5-50) . . .

The Appellants do not dispute the above findings (Br. 9-17, Reply Br. 1-4, and Supplemental Reply Br. 1-2). Nor do the Appellants dispute the Examiner's findings at page 5 of the Answer that:

> Edmond et al teaches a gallium nitride (GaN) layer co-doped with both a Group II acceptor and Group IV donor (col 4, In 50-67), where the group II acceptors include Zn or Mg and the Group IV donors include Si or Ge (col 6, In 20-50), this reads on applicant's the time for supplying each of the impurity raw materials are close to each other. Edmond et al also discloses the GaN layer is formed by CVD, where Trimethylgallium

> (TMG), ammonia, silane and biscyclopentadienyl magnesium, $(Cp)_2Mg$ are used as reactant gases (col 7, In 45-67 and col 8, In 1-50). [*See* Br. 9-17, Reply Br. 1-4 and Supplemental Reply Br. 1-2.]

Rather, the Appellants contend that Nishizawa and Edmond would not have led one of ordinary skill in the art to supply at least two (donor and acceptor) impurities close to one another at the time the first gas source, the Ga source gas-TMG, is introduced or before the second gas source, the As source gas-AsH, is introduced, to form a donor-acceptor complex in the resulting crystal layer (Br. 9-17).

The dispositive question is, therefore, whether one of ordinary skill in the art would have been led to employ the donor and acceptor impurities taught by Edmond in the manner taught by Nishizawa[2] in Nishizawa's process for growing doped semiconductor monolayers (crystal layers). On this record, we answer this question in the affirmative.

As indicated *supra*, Nishizawa teaches, *inter alia*, supplying impurities cyclically at the time of or during the cyclical introduction of the first gas source (the Ga gas-TMG) to form or grow either a p-type or an n-type crystal layer (*see* also col. 8, ll. 32-57). Nishizawa teaches that two impurities can also be introduced simultaneously at the time the first gas source (the Ga gas-TMG) is introduced (col. 8, ll. 47-50). Nishizawa goes on to state (col. 8, l. 58 to col. 9, l. 2) that:

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[2] The Appellants do not challenge the Examiner's determination at page 12 of the Answer that the "'close' timing means that the impurity is supplied at the same time, after or before the supplying of raw materials ([Specification,] page 3, line 22 to page 4, line 5)...." Therefore, we determine that the claimed timing encompasses the manner in which Nishizawa introduces its impurities.

> In this case, a molecular epitaxial growth layer having a desired distribution of the impurity concentration in the thicknesswise direction can be provided by setting the rate of supply of impurity gas to be lower than that of AsH_3 9 and TMG 8 . . . and setting the gas introduction time to 0.5 to 10 seconds. Further, it is possible to produce pn junctions, non-uniform impurity concentration distributions, bipolar transistor structures such as npn, npin, pnp . . . etc. by appropriately controlling the rate and time of supply of the impurity gases.

Although Nishizawa does not specify how the impurities are introduced to form a layer having pn junctions, e.g., a pnp bipolar transistor structure, Edmond teaches forming such layer by co-doping a gallium-nitride layer with both a Group II acceptor and a Group IV donor at a temperature high enough to promote the epitaxial growth of the Group II and IV compensated gallium nitride layer (col. 1, ll. 52-64; col. 2, ll. 54-65; col. 5, ll. 4-7; col. 6, ll. 22-46; col. 7, ll. 48-64; and col. 8, ll. 10-21).

Given the above teachings, we concur with the Examiner that one of ordinary skill in the art would have been led to supply both the acceptor and the donor impurities taught by Edmond in the manner taught by Nishizawa in Nishizawa's process, motivated by a reasonable expectation of successfully growing a layer having pn junctions useful for bipolar transistor structures. This is especially compelling in this circumstance since Nishizawa recognizes that the timing or sequence of the impurity introduction (doping) discussed above is a result effective variable in forming a desired crystal layer (col. 15, ll. 43-50 and col. 11, ll. 30-49). *Boesch*, 617 F.2d at 276, 205 USPQ at 219 ("[D]iscovery of an optimum value of a result effective variable in a known process is ordinarily within

the skill of the art."). Specifically, Nishizawa teaches (col. 15, ll. 43-50) that:

> [S]election of the timing of doping with respect to the source gas introductions is based on the desired dopant type for the monolayer being grown . . . , as well as the on the desired impurity concentration level. The determination of the sequence of source gas and impurity gas introductions is based on the type of impurity being doped.

Accordingly, we concur with the Examiner that Nishizawa and Edmond would have rendered the subject matter recited in claims 4 through 20, 26 through 28, and 33 through 35 obvious to one of ordinary skill in the art within the meaning of 35 U.S.C. § 103.

ISSUE 2 (Claims 21 and 36):

The Appellants contend that Nishizawa and Edmond would not have suggested employing TESi (tetraethylsilane) impurity. In response, the Examiner asserts that TESi and silane are equivalent Si impurity sources for doping "and substituting equivalents for the same purpose is obvious . . . (Answer 7)."

The dispositive question is, therefore, whether one of ordinary skill in the art would have been led to employ TESi in the process suggested by Nishizawa and Edmond. On this record, we answer this question in the negative.

As is apparent from page 8 of the Answer, the Examiner recognizes that Nishizawa and Edmond do not teach that TESi and silane are equivalent Si impurity sources for doping. Nor does the Examiner take official notice that TESi and silane are well known equivalent Si impurity sources for

doping. It follows that the evidence relied upon in making this rejection fails to support the Examiner's conclusion of obviousness.

Accordingly, we concur with the Appellants that Nishizawa and Edmond would not have rendered the subject matter recited in claims 21 and 36 obvious to one of ordinary skill in the art within the meaning of 35 U.S.C. § 103.

B. Claims 21 and 33 through 36 under 35 U.S.C. § 103(a) stand rejected as unpatentable over the combined disclosures of Nishizawa, Edmond, and Manabe.

ISSUE 3 (claim 21):

The Appellants do not dispute the Examiner's determination at page 8 of the Answer that:

> In a method of forming a gallium nitride compound semiconductor, note entire reference, Manabe et al teaches forming an n^+ type Gallium nitride layer, using silane or tetraethylsilane (TESi) (Example 4). It would have been obvious to a person of ordinary skill in the art at the time of the invention to modify the combination of Nishizawa et al and Edmond et al with Manabe et al because substituting known equivalents for the same purpose is obvious (MPEP [§] 2144.06). [*See* Br. 14-15, Reply Br. 1-4 and Supplemental Reply Br. 1-2.]

Rather, the Appellants contend that the prior art references would not have suggested the claimed timing or sequence of the impurity introduction (Br. 14-15, Reply Br. 1-4 and Supplemental Reply Br. 1-2).

The dispositive question is, therefore, whether one of ordinary skill in the art would have been led to supply the donor and acceptor impurities taught or suggested by Edmond and Manabe in the sequence and the manner

taught by Nishizawa in Nishizawa's process for growing doped semiconductor monolayers (crystal layers). For the factual findings set forth above, we answer this question in the affirmative. As indicated *supra*, Nishizawa teaches that the timing or sequence of the impurity introduction is a result effective variable.

Accordingly, we concur with the Examiner that Nishizawa, Edmond, and Manabe would have rendered the subject matter recited in claim 21 obvious to one of ordinary skill in the art within the meaning of 35 U.S.C. § 103.

ISSUE 4 (Claims 33 through 36):

The Appellants contend that Manabe does not teach supplying impurities in a pulsed manner (Br. 14-15). The Examiner, on the other hand, takes the position that the combined disclosures of Nishizawa, Edmond and Manabe would have suggested supplying impurities gases in a pulsed manner (Answer 8).

The dispositive question is therefore whether the combined disclosures of Nishizawa, Edmond and Manabe would have suggested introducing the suggested impurities in a pulsed manner. On this record, we answer this question in the affirmative.

As correctly found the Examiner (Answer 8), Nishizawa teaches repeating the introduction of impurities for a short period of time in a given sequence for every cycle (*see* the above undisputed findings from Nishizawa). This description, according to page 15 of the Brief, constitutes the supply of impurities in a pulsed manner. Thus, for the reasons indicated *supra*, we determine that the prior art references, as a whole, would have

suggested introducing the impurities suggested by Edmond and Manabe in the sequence and manner suggested by Nishizawa.

Accordingly, we concur with the Examiner that Nishizawa, Edmond, and Manabe would have rendered the subject matter recited in claims 33 through 36 obvious to one of ordinary skill in the art within the meaning of 35 U.S.C. § 103.

C. Claims 29 through 32 under 35 U.S.C. § 103(a) stand rejected as unpatentable over the combined disclosures of Nishizawa, Edmond, and Daly; and claim 32 under 35 U.S.C. § 103(a) stands rejected as unpatentable over the combined disclosures of Nishizawa, Edmond, Manabe, and Daly.

ISSUE 5 (Claims 29 through 32):

The disclosures of Nishizawa, Edmond and Manabe are discussed above. According to the Examiner (Answer, page 8-9), they do not mention employing impurities in "a predetermined ratio without incorporating disorder into said crystal layer" as required by claim 29. The Examiner then finds (Answer 9) that:

> In a method of making a strain-free GaAs device, note entire reference, Daly teaches the epitaxial deposition of a strain-free, carbon doped p-type layer in a GaAs device to from [sic.] the base layer thereof in a manner that includes the balancing of the strain of the crystal lattice structure caused by the carbon doping by co-doping the base layer with an isovalent and isoelectronic dopant, which also inhibits defect formation (Abstract), this reads on applicants without incorporating disorder into the crystal layer because strain from the impurity is balanced. Daly also teaches the amount of co-dopant required to counteract the carbon induced strain in the GaAs layer is proportional to the amount of carbon employed for p-doping (col 2, In 50 to col 3, In 20), this reads on applicants

> predetermined ratio. It would have been obvious to a person of ordinary skill in the art at the time of the invention to modify the combination of Nishizawa et al and Edmond et al by controlling the co-dopant to prevent strain as taught by Daly to form a strain free layer.

The Appellants do not dispute this finding or determination (Br. 16-17, Reply Br. 1-4, and Supplemental Reply Br. 1-2). The Appellants only specifically argue that Daly does not provide sufficient suggestion or motivation to employ the claimed predetermined ratio of the impurities to avoid "disorder" in the process suggested by Nishizawa and Edmond. *Id.* According to the Appellants *(id.)*, "strain" is not "disorder".

The dispositive question is therefore whether Nishizawa, Edmond, Daly and optionally Manabe would have suggested employing appropriate or optimum proportions of the donor and acceptor impurities to avoid "disorder" in monolayers (crystal layers). On this record, we answer this question in the affirmative.

Initially, we note that there is no indication that the amounts of impurities added in the process suggested by Nishizawa and Edmond causes "disorder". As such, we determine that Nishizawa and Edmond alone would have suggested the claimed proportions of impurities.

In any event, as indicated *supra*, there is no dispute that Daly would have suggested employing appropriate or optimum proportions of carbon and other dopants (impurities) to prevent strain in the monolayer (crystal layer). Daly shows a disorderly (strained) structure in its Figure 2. The Appellants do not point to anywhere in the Specification or other evidence to demonstrate that the claim language "disorder" excludes the disorderly structure illustrated in Daly's Figure 2. As such, we determine that

Nishizawa, Edmond and Daly would have suggested employing the claimed proportions of impurities.

Accordingly, we concur with the Examiner that Nishizawa, Edmond, and Daly would have rendered the subject matter recited in claims 29 through 32 obvious to one of ordinary skill in the art within the meaning of 35 U.S.C. § 103.

V. CONCLUSION

We have carefully considered the claims, Specification and prior art references, including the arguments advanced by both the Appellants and the Examiner in support of their respective positions. This review has led us to conclude that:

1) The Examiner's § 103 rejection of Claims 4 through 20, 26 through 28, and 33 through 35 as unpatentable over Nishizawa and Edmond is affirmed;

2) The Examiner's § 103 rejection of claims 21 and 36 as unpatentable over Nishizawa and Edmond is reversed;

3) The Examiner's § 103 rejection of claims 21 and 33 through 36 as unpatentable over Nishizawa, Edmond, and Manabe is affirmed;

4) The Examiner's § 103 rejection of claims 29 through 32 as unpatentable over Nishizawa, Edmond, and Daly is affirmed; and

5) The Examiner's § 103 rejection of claim 32 as unpatentable over Nishizawa, Edmond, Manabe, and Daly is affirmed.

Accordingly, the decision of the Examiner is affirmed for the factual findings and conclusions set forth in the Answer and above.

VI. TIME

No time period for taking any subsequent action in connection with this appeal may be extended under 37 C.F.R. § 1.136(a).

AFFIRMED

tf/ls

Birch, Stewart, Kolasch & Birch
P.O. Box 747
Falls Church, VA 22040-0747